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EPA/ORD Role and Perspective in Sediment Research

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16. ABSTRACT

This document addresses regulatory applications, current and future sediment quality criteria needs, and both chemical specific and nonchemical specific sediment quality evaluations. Mitigation/prevention of sediment quality problems are identified and five kinds of predictive methods are suggested, as well as future research to develop more sensitive testing capabilities.

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MONITORING OF SEDIMENT QUALITY

Monitoring benthic ecosystems is required under a variety of current EPA regulatory programs, including ocean dumping, estuarine and wetland protection programs and NEPA review. It is likely to increase in importance as EPA's interest in sediment quality expands. Some sediment monitoring methods are well established but others require development or refinement. Monitoring requirements have changed as knowledge of benthic processes has increased. Some very basic monitoring needs remain unresolved. For example, there is a need for chronic full-life-cycle toxicity tests to cost effectively monitor sediment quality. In addition, there is no standard method for collecting and processing interstitial water.

CURRENT MONITORING OF SEDIMENT QUALITY

Present research on sediment monitoring methods is not well coordinated. There are projects on optimal benthic community survey techniques in progress in Regions V, IX and X. Monitoring of sediment toxicity and bioavailability is not an active research area, and the use of biomarkers and interstitial water quality is rare in benthic monitoring. Integration and comparison of sediment survey methods is virtually non-existent.

FUTURE MONITORING RESEARCH

Phase I research in this area will concentrate on the development of chronic, full and partial life-cycle toxicity tests for benthic freshwater and marine species. There is a critical need for these tests, which are more sensitive than the existing acute toxicity tests, for assessing sediment toxicity and for evaluating the various methods for developing sediment quality criteria described in the Sediment Quality Criteria (Chemical Specific) section.

Phase II research will develop and evaluate several additional kinds of sediment quality monitoring techniques, including benthic community structure, interstitial water quality, bioavailability, and biochemical markers. The interstitial water quality techniques wili allow direct comparison of field conditions with sediment quality criteria based on the equilibrium partitioning theory. Biochemical markers will be adapted to sediment monitoring for the first time. Individual monitoring methods will be developed and tested against specific sediment contaminant gradients, and the different methods will be compared at selected freshwater and marine sites representing different kinds of sediment pollution.

In summary, ORD research efforts will continue to support the application of the various approaches of addressing contaminated sediments. The degree and timing to which ORD can undertake all the required tasks will depend on availability of resources. Current indications are that additional researchers and extramural dollars will be assigned to the sediment quality research program.

INTRODUCTION

Most chemical contaminants and organic wastes in aquatic ecosystems eventually accumulate in sediments where they may adversely affect the benthic biota, become a source of contamination in the water column, accumulate in biological tissues, and enter pelagic and human food chains. Contaminated sediments now appear to be the main source of toxic pollutants in many bays, lakes, and rivers. Because of their potential adverse impacts, the long periods of time associated with natural assimilation of many in-place pollutants, and the high costs of mitigation, sediments have become a focus of concern for many of EPA's research and regulatory programs. Programs in which sediment quality assessments are currently required include ocean dumping, NEPA review, Superfund, and estuarine protection.

Historically, ORD had been conducting research on characterization and impact of contaminated sediments. The program was disbanded in 1983 because it did not contribute to the mission of the Office of Water.

REGULATORY APPLICATIONS OF SEDIMENT QUALITY CRITERIA

In 1985 a new sediment quality research program was initiated at ERL-Duluth and ERL-Narragansett to develop sediment quality criteria (SQC) that define safe concentrations of individual chemicals in sediment. SQC are needed to provide a chemical-specific basis for evaluating sediment pollution in relation to Superfund remedial action plans, dredged material disposal decision, sediment wasteload allocations, 301(h) analysis of benthic degradation, compliance monitoring, and other regulatory schemes (Table 1).

Chemical-specific sediment quality criteria provide the most efficient regulatory strategy for relating benthic ecosystem degradation to specific contaminants and sources. Other approaches for evaluating sediments, including bioassays of total sediment toxicity and benthic community structure analysis, do not reveal the relationship between benthic impacts and causal factors. The present SQC research program must be expanded to develop chronic test methods, augment toxicological databases, compare equilibrium partitioning, apparent effects threshold, and bioassay/toxicological test methodologies for developing SQC, and integrate available methods into a comprehensive approach for assessing and regulating sediment pollution.

CURRENT SEDIMENT QUALITY CRITERIA RESEARCH PROGRAM

ORD's present SQC research program is oriented toward the equilibrium partitioning approach and most toxicological research has been conducted to test predictions of that approach. In the equilibrium approach, interstitial water concentrations of individual chemicals are predicted from equilibrium partitioning theory and compared with water quality criteria. The equilibrium partitioning approach has been most successful with respect to criteria for neutral organic compounds. Some research on the partitioning, toxicity, and bioavailability of metals in sediment has also been conducted. The apparent effects threshold (AET) approach has been developed primarily by Region X. Development of screening-level criteria has not been pursued to the same extent as the equilibrium partitioning approach. Modeling efforts include fundamental process studies, adsorption of ionizable organics, and field

testing a sorption model for metals on aquifer solids. Although the different approaches to development of SQC are complementary, there has been little integration of these efforts. There has been little laboratory, and no field, verification of SQC approaches under the ORD based program.

FUTURE SEDIMENT QUALITY CRITERIA RESEARCH

Future research efforts have been developed in phases which are dependent upon funding levels. In Phase I, field and laboratory investigations will be conducted to compare approaches for developing numerical SQC, including equilibrium partitioning, AET, and toxicological techniques. Field and laboratory data will be developed from a variety of freshwater and marine sites to expand the geographic applicability of the AET approach. Comparative toxicological databases, generated through use of chronic full-life-cycle toxicological tests to be developed under the Monitoring of Sediment Quality research area, will be used to derive contaminant-specific SQC and to recommend minimum test requirements for non-contaminant-specific sediment quality evaluations. Interim guidance documents on regulatory applications of SQC derived from a variety of contaminant-specific methodologies will be developed for selected priority chemicals.

In Phase II, research on the equilibrium partitioning, AET, and bioassay approaches for development of sediment quality criteria will be expanded. The equilibrium partitioning research will focus on SQC for metals, minimum toxicological data sets for extrapolation from water to SQC, and field validation of proposed criteria. Research on the bioassay method will develop toxicological and bioaccumulation estimates of safe sediment concentrations for a set of fifteen priority chemicals. Correlations between contaminant concentrations, toxicity, and benthos distributions along pollution gradients at representative field sites will be used to investigate the AET method and to estimate SQC empirically. The different approaches to development of SQC will be compared and integrated for the assessment of a greater number of priority contaminants than in Phase I.

There will be a more comprehensive integration of the equilibrium partitioning hypothesis with other toxicological methods and field observations. Estimates of safe contaminant concentrations through classical dose-response experiments will be conducted for representative sediment types. Research comparing the relationships between organism tissue residues and toxic responses and estimates of sediment-to-organism bioaccumulation factors will be used to develop and evaluate SQC applicable to site-specific conditions.

Predictive models will be developed to estimate the equilibrium partitioning of ionic organic compounds to sediments. A benthic exchange model will be developed to quantify the effects of sorption, diffusion, bioturbation, and sediment transport. Final guidance documents on regulatory applications of SQC will be developed and transferred.

SEDIMENT QUALITY EVALUATION (NON-CHEMICAL-SPECIFIC)

Assessment methods for evaluating sediment quality cannot always be based on chemical-specific criteria because of the great number of potentially hazardous chemicals in sediments. Further, under some regulatory strategies it is necessary to directly examine sediment toxicity and carcinogenicity, the

condition of benthic resources, and physical characteristics. There is some technical evidence that SQC cannot accurately be applied on a chemical-specific basis without some knowledge or estimate of the joint actions among contaminants, which are typically found in mixtures in polluted sediment. Non-chemical-specific methods are often needed for sediment quality evaluation. Evaluation of sediment quality on the basis of biological impacts, toxicological effects, or contaminant interactions requires a better understanding of how benthic ecosystems respond to sediment degradation.

CURRENT SEDIMENT QUALITY EVALUATION (NON-CHEMICAL-SPECIFIC)

EPA is currently funding a number of studies to describe the degradation and recovery of benthic ecosystems. Sediment characterization studies are being conducted to assess the stresses placed on the benthic systems. These projects are often based on correlations between sediment physical characteristics, contamination, disease, toxicity, and biological effects.

The critical need that is not being adequately addressed is an examination of causal relations among these factors. Regulations that require sediment quality evaluation can be fully successful only if there is certain knowledge that ecosystem perturbations are causally related to sediment pollution. Effects of mixtures of sediment contaminants are almost completely ignored in present research efforts.

FUTURE: SEDIMENT QUALITY EVALUATION RESEARCH

All research in this area will be conducted under Phase II. Several key problems in sediment quality evaluation will be examined, including:

- The assimilative capacity of benthic ecosystems for organic enrichment and sediment contamination will be examined in relation to the development of new regulatory strategies for controlling benthic pollution. One objective of this project will be to determine chemical and enrichment effects on benthic communities.

- Sediment toxicity will be related to its functional significance, including the elimination of benthic populations and consequent loss of trophic resources for commercial and recreational fisheries. This examination of the relevance of sediment toxicity will provide a stronger technical basis for the use of sediment bioassays as regulatory tools. In addition to toxicity, comprehensive assessments will include mutagenicity, genotoxicity, carcinogenicity, and fish tumor incidence.

- Models of the joint action of mixtures of sediment contaminants will be used to predict the total toxicity of field and experimental sediment in terms of the effects of additivity on sediment quality criteria.

- Data from field correlations will be used to design definitive experiments to demonstrate causal relations between sediment contaminants and the incidence of fish disease.

- The assessment of key physical characteristics that determine resuspension and contaminant flux potential is needed to determine the vulnerability of ecosystems.

- Data from field correlations will be used to develop a comprehensive assessment protocol.

- A strategy will be developed to characterize and identify the specific chemicals causing toxicity in contaminated sediments.

MITIGATION/PREVENTION OF SEDIMENT QUALITY PROBLEMS

A key sediment issue faced by a regulatory agency is how to prevent or mitigate the ecological damage caused by benthic pollution. Regulatory decision makers need predictive methods to describe contaminant deposition and distribution, bioaccumulation, toxicity, and ecosystem recovery. An essential element in developing a remedial action plan is the ability to predict rates of natural burial of contaminated sediments. Problems associated with the removal and disposal of contaminated sediments make the "do nothing" option an important consideration. To effectively use this option, regulators must be able to predict the rate of sediment deposition and the frequency of suspension and contaminant exposure.

Five kinds of predictive methods must be developed and validated through field measurements:

- Transport/deposition model to relate in-place sediment contaminants to specific sources.

- Wasteload allocation strategy for sediment contaminants.

- Models of benthic community degradation and recovery.

- Models of acute and chronic toxicity and bioaccumulation.

- Microcosms to simulate specific remedial actions, such as dredging and capping.

One of the most common sediment mitigation procedures is to dredge contaminated sediments and dispose of them in another location. For a variety of reasons, the disposal site is often in a wetland or an area that runs off into a wetland. While filling wetlands has an obvious impact, the effect of contaminants associated with the disposal of dredged material on wetlands is generally unknown. Information regarding the impact of chemicals on wetlands would provide regulators and permit writers additional guidance to use in making decisions on the appropriateness of disposal options.

CURRENT RESEARCH IN MITIGATION/PREVENTION OF SEDIMENT QUALITY PROBLEMS

Some of the research necessary to develop predictive methods for the sediment program has already begun, though the level of effort is insufficient to meet all research goals. The one research area that has been well developed, by the Corps of Engineers and EPA, concerns the effects of dredging and dredged material disposal. ORD started an initial project on sediment wasteload allocation in FY'88. Two projects on particle deposition and resuspension models have been supported by the 301(h) regulatory program. Uptake of pollutants from contaminated sediments through the food chain is an integral part of the mass balance model being developed for Green Bay, Michigan. The current wetland research program includes efforts on the mitigation of damaged or lost wetlands, the impact of cumulative losses of wetlands, and the functions of wetlands in improving water quality. However, this research does not include empirical studies on the effects of sediment contaminants on the biological components and processes of wetlands.

Predictive models for toxicity and ecosystem alterations are not available. Conceptual models of the bioaccumulation of sediment contaminants have not yet been quantified. Microcosms have not been applied to simulate sediment capping or other remedial actions that might be implemented at aquatic Superfund sites.

FUTURE RESEARCH IN MITIGATION/PREVENTION OF SEDIMENT QUALITY PROBLEMS

Phase I will focus on models of particulate deposition and resuspension, and predictions of the biological impacts of contaminated sediments. The ability to predict the fate of sediment contaminants will be advanced by strengthening research on deposition/resuspension models. Such models can be applied to a diversity of regulatory issues including source identification, wasteload allocation, nutrient release, and the question asked with increasing frequency: "What will happen if nothing is done?" Research on predictions of biological impact will address toxicity, bioaccumulation and community recovery.

Phase II will focus on simulation of remedial actions, predicting the effects of toxic chemicals in the Great Lakes and wetlands, and refining methods for predicting the biological impacts of contaminated sediments. Microcosm research will initially consider the efficacy of alternative sediment capping options in open waters.

Research on the effects of toxic chemicals on wetlands will be conducted with experimental wetlands that can be stressed under controlled conditions. Dose-response curves are necessary to provide input into risk assessments and management decision schemes. Experimental wetlands provide the opportunity for controlling chemical inputs and for replicated exposures. Experimental wetlands at the Monticello Ecological Research Station would be used to determine the impact of sediment related contaminants on the biological activity under known exposure situations. The effect of contaminant additions to wetlands could be evaluated to systematically evaluate the potential for impact from chemical contaminants of sediments and dredged materials. This information will then provide guidance for appropriate sediment mitigation options.

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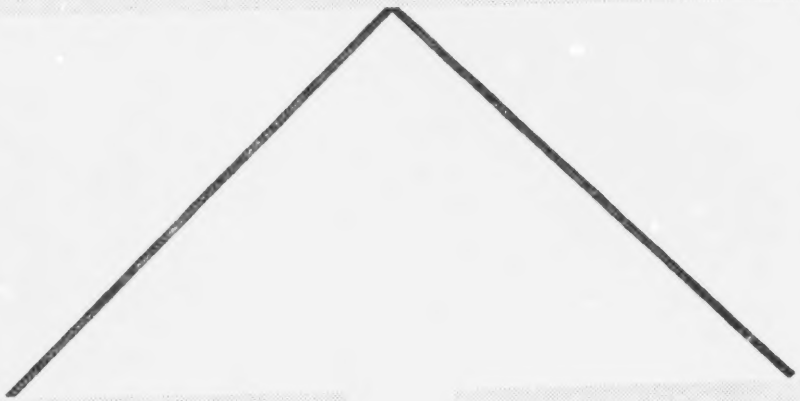
APPLICATIONS OF SEDIMENT CRITERIA IN IMPLEMENTING MAJOR ENVIRONMENTAL LAWS

	1977 CLEAN WATER ACT	1987 AMENDMENTS	OCEAN DUMP ACT	RESOURCE CONSERVATION AND RECOVERY ACT	SUPERFUND SARA
DUMPSITE DESIGNATION	X		X	X	X
DISCHARGE SITING	X	X			
PERMIT DECISIONS	X	X	X	X	
DUMPSITE MONITORING	X	X	X	X	
DISCHARGE MONITORING	X	X		X	
CLEAN AREA IDENTIFICATION	X	X		X	X
CLEAN-UP AREA SELECTION	X	X	X	X	X
CLEAN-UP GOAL SETTING	X	X		X	X
SITE RESTORATION	X	X			X
EIS PREPARATION	X		X	X	X

MITIGATION/PREVENTION



SOURCE LIMITATIONS

Assimilative Capacity

Particulate Adsorption

Chemical Fate

SITE CORRECTIONS

Removal (Contaminant Characteristics)

Deposition (Burial)

Degradation